

ON THE

# ARCH OF THE FOOT.

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DEDICATED TO

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FIG. 1 is copied from "Human Osteology," by permission of my old teacher and friend, Mr. HOLDEN; and in respect of FIG. 2, I am under a similar obligation to the publishers of "Gray's Anatomy," Messrs. Longman and Company.



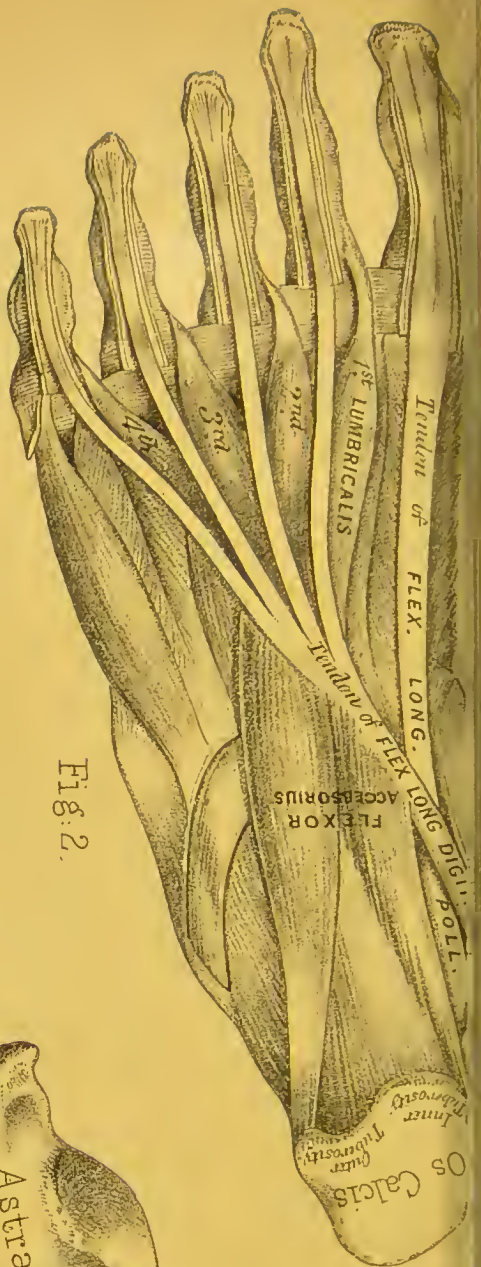


Fig. 2.

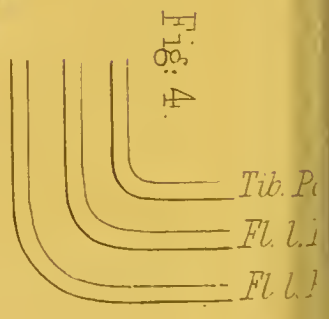


Fig. 4.

Fig. 3.

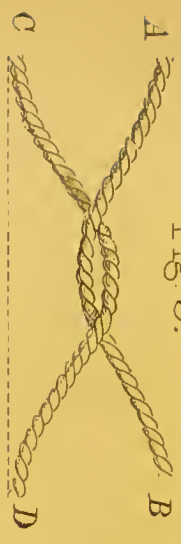
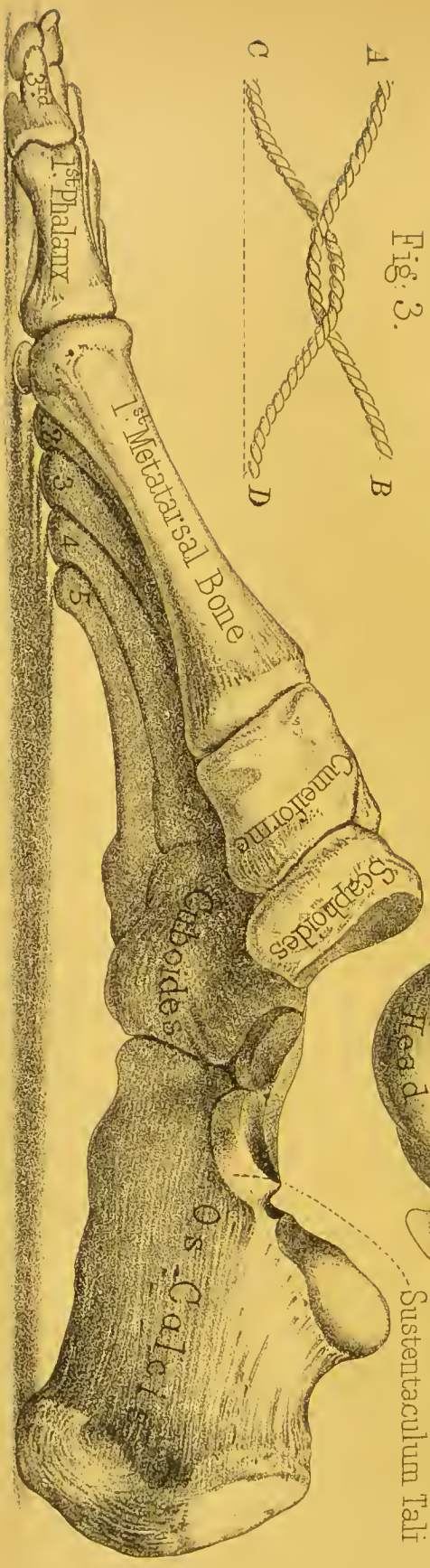


Fig. 1.



## ON THE ARCH OF THE FOOT.

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**A**N Arch, in an architectural sense, is defined as “a self-sustaining structure,” but no architect would construct one intended to bear weight, without provision for the “lateral thrust” which the weight would occasion.

Such provision, the more necessary where the voussoirs move upon each other, and where the pressure is liable to vary in direction, is made in the arch of the foot in the form of ligaments of unusual strength, and it is upon them, *as is generally represented*, that the support of the arch mainly depends.

My own observations, following upon an event to be presently spoken of, have convinced me that it is by muscles that the support of the arch is chiefly effected—at least during movement—and that the chief influence is what I propose to call the *bow-string* action of the deep muscles of the back of the leg, an influence which, from a surgical point of view, as far as I am aware, is nowhere set forth.



Taking the *flexor longus pollicis* as one of these muscles, its tendon, passing from one end or abutment of the arch to a point very near the other, that is from the proximal end of the great toe to a point considerably below the "sustentaculum tali," shewn in fig. 1, is tightened when the muscle is in action, and it is clear on looking at that figure that any tension of this tendon must throw up the arch which is above it as certainly as tightening the bow-string increases the convexity of the bow.

This muscle, with the *flexor longus digitorum*, the short flexors in the sole, the abductors of the great and little toe, the adductor of the great one, the *lumbricales*, and the *accessorius*, all these, themselves or their tendons, fulfil with more or less advantage the relations of chords to an arc, or of segments of an arc. So also do the *peronei* (*longus* and *brevis*), especially the former.

But under what circumstances do these muscles act? Individually they are adapted to special movements, but such action is not much called for. In reality few people give their feet more than very little exercise except in walking, yet these muscles are invariably well developed if the muscles of the calf are found to be so.

But are they used in walking? The first movement in this act is described by Dr. Carpenter



(Human Physiology, 7th ed., p. 767) as follows: "Standing firmly with the left leg in advance, the first act consists in raising the heel of the right foot, which is accomplished by the gastrocnemius and soleus muscles; and the weight of the whole body thus raised . . ."—while Professor Humphry, in his well-known book on the foot and hand, thus describes it: "The raising of the heel is accompanied by a rolling of the foot *inwards*, and by an increased flexure of the plantar arch," . . . a "movement effected mainly by three muscles, of these one (gastrocnemius and soleus) raises the heel while the other two (tibialis posticus and peroneus brevis) raise and support the ankle," going on to say that the first named combined muscle may well be of great strength, "for in raising the heel it has to support the whole weight of the body." It seems to me, however, that while there are muscles occupying a position in which, if of sufficient strength, they might of themselves raise the body, and seeing that they are in fact very powerful, it ought not to be assumed or implied that they have no part in the matter.

That they do come into action in walking is recognized in some books on anatomy, and may be, by a simple experiment, easily proved. When the body is erect, with each foot resting evenly on the ground, it will be found that the great toe as well as the little ones can be readily

lifted, and the tendons behind either ankle can hardly be felt ; but let an attempt be made to raise one heel and to support the body in that position—which is the first act in walking—immediately the tendons start out and it becomes impossible to lift the great toe, while as regards the smaller ones they are seen to be flexed on themselves as if to give a grip of the ground, against which the ends are firmly pressed.

This grip of the ground by the small toes is attended with a throwing up of the joints between the 1st and 2nd phalanges, due to the insertion of the flexor tendons to the joint between the 2nd and 3rd phalanx, a line of projections across the little toes being so formed as the muscles act ; this condition becomes in a slight degree permanent, not at all depending on tight boots, for it is seen in the best formed feet, and is so represented in the best statuary. The great firmness and solidity of the great toe, with the tendon of its strong flexor muscle fixed to the joint between the only two phalanges comprising it, thus preventing any uprising there, allows the great toe to be used as a firm fixed point or fulcrum from which the body can be propelled onwards, its strong flexor muscle being a powerful agent in doing so.

Thus, then, it has seemed to me that, in the act of walking properly performed, the arch of the foot is really supported by the muscles,

acting as bow-strings, tightening at every step, and that it is only while at rest that the ligaments alone bear the weight of the body ; and this conclusion corresponds with the fact that a sinking of the arch occurs in those who stand rather than in those who walk, and that it is always associated with a weak, ill-developed muscular system, or else with a habit of wearing such heavy or unyielding boots as prevent muscular action.

Moreover, the arch of the foot increases from infancy to adult age, scarcely existing at all in the infant, which is difficult to understand on any theory of development without some physical influence to direct it ; and that ligaments alone would support great weights for long periods of time unassisted by any muscular influence without a considerable yielding has seemed to me improbable, a feeling increased by an investigation of the ligaments of the foot to be presently referred to.

It must be remembered that, although "plantigrade" when walking, man becomes in running and in climbing "digitigrade," and the strain upon the ligaments of his foot, unsupported by muscles, would be tremendous ; so much indeed that, from all we know of ligamentous tissue, it must, under such circumstances, give way.

Take, as a familiar instance of a digitigrade animal, a horse. No one supposes that as the

body is propelled onwards, or upwards over a fence, the weight of it is supported from the toe to the heel, that is, the hock, by ligaments entirely ; of course the contraction of the great flexor muscles acting on the tendon which passes behind the foot, the so-called "leg," affords the necessary support, and as this tends to give the "fetlock" joint a curve forwards, so when the muscles have been strained beyond their powers of resistance, and the weight thrown against the ligaments, a condition of "straight joints" is the consequence.

My attention to everything which bore on this subject was forcibly directed by the following circumstances :—

In August, 1867—just ten years ago—it was my misfortune to have, in addition to a fracture of the fibula, my own right foot crushed between the body of a horse and the stones of a street crossing—the scaphoid bone was dislocated inwards, the middle cuneiform upwards, and the cuboid downwards—as is evident to this day ; great laceration of the ligaments of course occurred, with a terrible amount of contusion and consequent swelling.

To do more than keep the limb in position for the fracture to unite was out of the question ; the displacement of the tarsal bones must of necessity have been disregarded even if the nature of it could have been determined,

My friends who took charge (Dr. BATTEN with Mr. GRAVES) having done all that was possible by professional skill and personal kindness to relieve the severe suffering, and bring about a state of convalescence, I left home, the case passing into my own hands; and when, some three months after the accident, the foot was brought into use, what remained of the arch soon disappeared.

About three months later on, having had all manner of advice given me, such as to lay up in town, and have the peronei tendons divided, and on the other hand to leave it alone altogether, Mr. HEATHER BIGG constructed a boot, most admirably devised and executed, with which I could walk well, and which soon restored to some extent the lost arch; but this was on the principle of forcing it up mechanically, and the force being removed it soon sunk again. This contrivance I used at intervals for some years, but so irksome was it to wear an apparatus, of necessity cumbersome, that I was always glad to avoid using it. The foot was, however, at times so flat and so painful that I was compelled to resort to the instrument.

However, having come to the conclusion that the ligaments, once so thoroughly torn, could never again be strong enough of themselves to carry the weight of the body, I got into the habit of giving the muscles all the exercise I



could while in the recumbent position. I did this because pain prevented me from giving them any exercise while walking, without any definite idea of the advantage to be gained, beyond trying to prevent the tendency to eversion, and to promote the general bracing up which such exercise involved ; but about Christmas, 1873, more than six years after the accident, I had decided that what I called the *bow-string* action of the muscles was the help to be relied on, and I commenced the following plan :—

To walk as much as I could do with a well-marked heel to toe action and no more ; frequently and for increasing periods to raise the heel from the ground while standing on the affected foot, with as little support as I could do with till I could dispense with it altogether ; then to walk about on tip-toe as much as possible ; all this, often very painful, especially in commencing after long rest, was steadily followed for six months, by which time the improvement was most marked. I could then hop over a footstool without difficulty or pain, though on commencing I was unable even to stand on tip-toe, and had not done so since the accident, or gone up-stairs otherwise than by planting the lame foot sideways on the step.

From then until now the foot has never given me any serious trouble ; I have been able to do as much walking as time and the avoidance of

general fatigue has allowed. The bones being still out of place, the foot is of course defective, and the arch—if it may be so called—a poor one, though a very marked contrast to the absolutely flat foot there was. I get a little pain in commencing to walk after rest following any unusual exercise, but it is for a few steps only; this I attribute to the tarsal bones not pressing evenly on each other in their displaced positions, and requiring a little pressure to bring them into the position in which they have come to fit each other.

Naturally I attach much importance to a plan of treatment which, reasoned out beforehand, I applied with so much benefit to myself. Moreover, the case seems to me interesting on another ground—of all the excellent surgeons, some of them since dead, who gave me their opinions, with a kindness of which I have a grateful recollection, not one gave me the slightest hope of any improvement beyond what time and mechanical support would give; as to time, six years after the accident the foot was little, if any, better than at the end of the second, while all the good which mechanical support could do was undone directly it was removed.

Yet a careful reference to the *anatomy* of the affected part put me in the way of a recovery almost complete; but not to human anatomy alone, for it was not until I thought of the



enormous weight which must fall upon the tendon of the "*foot*" of the horse, that full conviction was attained that muscles, if only strong enough, would support my damaged ligaments, and restore my flattened foot.

But although comparison of corresponding parts in one of the lower animals was of advantage, it seems hardly too much to say that anatomically there is no more marked distinction to be found between them and man than in the arch of the foot—in other words, in his heel and in his great toe :

The heel projecting so much as to completely cut off the fascia and the muscles of the sole from their corresponding and *typically* continuous parts in the leg, yet not projecting so far beyond the outline of the leg but that it is balanced, as regards contour, by the prominence of the muscles of the calf, while their corresponding increase of strength compensates for the loss of leverage which a further projection of the heel would afford.

This hard bony heel directed downwards, upon which the whole weight of the body can be suddenly thrown and maintained at will, seems especially adapted for crushing anything beneath it, and without going into discussions of the special significance which the frequent use of the word in the Bible and elsewhere might suggest, it may be remarked with reference to

the promise that it should "bruise the serpent's head," that man alone has a *heel* adapted for such a purpose, and further, that the Arabs, the race which occupies the Ancient Palestine, more than any people in the world, attach importance to a well-arched foot as a mark of superiority, that is to a well-pronounced heel projecting downwards, not backwards, as in the negro, a sign of degradation.

Of the great toe, Professor FLOWER (*Osteology of the Mammalia*) says:—"The hallux is much "stouter than any of the others, though usually "not quite so long as the second toe. Its "metatarsal bone is articulated to a nearly flat "surface on the internal cuneiform, directed "distally, so that it is placed in the same plane "as the other toes, and cannot be freely separated from, or opposed to them." All this is in marked contrast to what exists in other "Primates," and although in them as in other animals special developments of this or other toes may occur, and special arrangements of the muscles moving them, they are in no case adapted to the same end as in man, for standing and for moving in the erect posture.

Of the muscles concerned, it may be remarked with regard to the *flexor longus pollicis*, which, as I hold, plays a most important part in sustaining the arch:—

1st.—That as the arch of the foot is by far the most marked on the inner side, (Fig. 1) this

muscle, which is very strong, being as large or indeed larger than the common flexor of the toes, has an unyielding attachment in the great toe, and is directed in a line along the inner side of the foot from one extremity of the arch nearly to the other, in strength having (with the small flexor), a proportion to the common flexors of the toes very different to the proportion between the flexors of the thumb and the common flexors of the fingers.

2nd.—That it passes round the ankle on a plane lower than the *flexor longus digitorum*, as if to act at the greatest advantage on the arch; but as in this position, however much it forced it up, it would do little to increase the hollow of the foot—little towards attaining the Arab standard of a foot that water will flow under—the tendon of this muscle is curiously displaced from its position, and passes under it, as shewn in fig. 2, so that when acting at the same time it forces up the *flexor longus pollicis*, so as to leave the space underneath, having in fact an influence like the upper of the two cords A, B, in fig. 3, which passes round the lower one and directs its course upwards, away from the dotted line C, D; this action being assisted by the *accessorius*, which, drawing the common flexor towards the medium line, compels these two tendons to cross at a point further back, and therefore higher up than they otherwise

would do, as seen in fig. 2, while the superficial parts of the sole are drawn up with it, by means of the strong fibrous bands which dip down to the plantar fascia.

3rd.—This muscle, which acts on the inside of the foot, arises from the outside of the leg, giving it an obliquity which is in no way due to any adductor or pronator action, because, having its tendon fixed in grooves around the ankle, its line of traction would be the same if it arose from any other point ; its origin from the fibula would seem to be determined by that bone, occupying typically a posterior, or as Professor Huxley calls it a “post-axial” position. If, then, the fibula were rotated to that position, the origin of the muscle would correspond to its course, as in fig. 4 ; but even then it would be different to the deep flexor of the thumb, which has a radial or pre-axial, while the common flexor has an ulnar or post-axial origin.

4th.—Its tendon is attached to the great toe only, and the muscle is completely divided, or “segmented” from the rest of the pronato-flexor group in the calf, though it arises from an inter-muscular septum with the *peroneus longus*, one of the supinato-extensor group, with which muscle it is generally associated in action, not only in walking but in flexing the foot.

Of this last named muscle it may be said that, although acting by itself it is a powerful

abductor, when that action is prevented by other muscles, it comes of necessity to have a flexor action, and in walking does so act. My friend, Mr. HOWARD MARSH, has called my attention to some papers in the *Archives de Médecine* by Dr. DUCHENNE, of Boulogne, in which he attributes a form of flat foot ("pied plat douloureuse") to a defective action ("impotence fonctionnelle") of this muscle—he says, "le long péronier est le formateur, et pour ainsi dire la clef de la voûte plantaire ; Eh bien ! le jambier antérieur en est le destructeur." There is no allusion to the *flexor longus pollicis* or other muscle as having any share in forming the arch.

That the long peroneal has, with the other muscles, an influence in forming the arch is what I have stated, but how the anterior tibial can be in any sense a destroyer of it I fail to see any more than I can understand why the former should be, of a system of muscles, the one to be so often smitten with "impotence fonctionnelle." As to its influence in *forming* the arch of the foot, I may add that Mr. SALT, the instrument maker of Birmingham, in a book on deformities published some ten or more years ago, speaks of the arch of the foot as being formed after infancy by the action of this muscle.

I feel it to be some apology for publishing the conclusions to which my study of the subject has led me, that what Dr. DUCHENNE speaks of



as the “formatcur” of the arch of the foot, an eminent orthopædic surgeon proposed to divide in my case as a part of the treatment he proposed.

Professor HUMPHRY has given a curious instance of contrast between one muscle belonging, like the *peroneus longus*, to an *extensor* group, and having a *flexor* action, with another in which the order is reversed; in the two-toed Sloth, (Unau,) the *tibialis anticus* terminates in the *flexor digitorum*, while in the rabbit, the tendon of the *tibialis posticus* curves over the scaphoid bone, and terminates in the *extensor* tendon of digit II.

With regard to the *tibialis posticus*, a careful examination renders it difficult to see how, supposing this muscle to maintain fully its tone, the arch of the foot can sink. Passing below the head of the astragalus, and inserted really into all the tarsal and metatarsal bones it can reach, its tendon is in fact a great suspensory ligament of the arch, and while it is tense and in its proper place, the arch cannot fall; and though the ligament uniting the os calcis to the scaphoid is on the outer side made of strong straight shining fibres, with little appearance of elastic tissue element, it is very much weaker on the inner side where it has the tendon to support it.

A word as to the influence of ligaments in giving a “spring” to the foot. The very short

length of them seems to forbid the idea that they can allow of much spring action, nor does it appear that any ordinary force can do more than very little to cause it. Spring action, whether it be in walking or jumping, is largely due to muscular influence holding the foot first on the toes, then letting it down firmly and gently; and although a springy gait and well-arched feet go often, not always, together, it appears that this condition of foot is a consequence, at least as much as it is a cause, of the manner of walking. At the same time, I see no reason to doubt that the ligaments do yield when the muscles are not in action; but the consequent lengthening of the foot is mainly on the inner side, at the part corresponding to the tendon of the *tibialis posticus*, rather than that held in place by the outer and stronger part of the *calcaneo-scaphoid* and the *calcaneo-cuboid* ligaments.

Still, in a state of rest the weight of the body must rest entirely or almost entirely on the ligaments, and this is a strong reason for not allowing children with weak muscles to stand for long periods, and why those whose occupations require them to stand much should occasionally raise the heels from the ground, so as by muscular action to relieve the pressure on the ligaments. On the same principle, the evils of a "slouching" or "stumping" gait, and the advantage of a proper mode of walking,



cannot be too strongly urged, and that no more walking should be done than can be done properly.

For if the views I have expressed are true, the principles involved of course hold equally well for the treatment of flat foot not arising from injury, and such experience as I have had gives me no reason to doubt them; but it is sometimes with patients as with Naaman the Syrian—they are more likely to accept directions to do “some great thing” than to carry out a tedious plan, in which they see only a very mild attempt to meet a very serious trouble.

Sir JAMES PAGET a year or two since told me of a dancing master, living many years ago at Windsor, who was accustomed to tell his pupils to cure flat foot by never standing except on tip-toe, and to do this always when dressing. This is the only instance I have heard of in which a similar plan to the one I carried out for myself has been recommended, nor have I been able to find or to hear of anything of the kind in books; and that these views are not generally accepted appears from the fact that eminent surgeons do order “surgical soles” in cases where, as I think, a skipping rope would be a far better prescription.

Mechanical aid may in extreme cases be needed to give the foot a start, so to speak,

from the straight line, but for all ordinary cases I am sure that well directed exercise is the proper treatment. Galvanism, too, may in some cases be necessary to arouse inactive muscles ; nor do I underrate the importance of *rest*, which in a malady often depending on muscular fatigue is of course specially necessary, but as, when the arch of the foot is lost or failing, muscular action alone can restore it, so exercise must always be insisted on, without which even the necessary muscular development is impossible.

